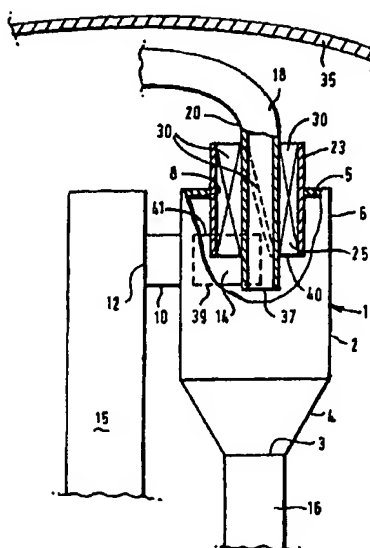




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(54) **CYCLONE**  
(54) **CYCLONE SEPARATOR**



(57) L'invention concerne un cyclone (1). Celui-ci comprend un carter vertical (2) ouvert au niveau de son extrémité inférieure (4), pourvu d'un couvercle (5) au niveau de son extrémité supérieure, dans lequel est ménagée une ouverture centrale (6). Il comporte également une conduite d'entrée (10) pour assurer une entrée tangentielle d'un mélange de gaz et de particules de catalysation provenant de la sortie (12) d'un réacteur à colonne montante (15) d'une installation de craquage catalytique à lit fluidisé. Ce cyclone comprend également une conduite de déchargement des particules (16) communicant avec l'extrémité inférieure ouverte (4) du carter vertical (2), et une conduite de sortie des gaz (18) dont une section verticale (20) s'étend à travers l'ouverture centrale (6) ménagée dans le couvercle (5). En outre, ce cyclone (1) comprend un tube à extrémité ouverte (23) placé dans l'ouverture centrale (6) afin de définir une conduite d'entrée de gaz annulaire (25) entre la section verticale (20) et le tube à extrémité ouverte (23) et des moyens (30) assurant un tourbillon, placés dans la conduite d'entrée de gaz annulaire (25).

(57) Cyclone separator (1) comprising a vertical housing (2) open at its lower end (4) provided with a cover (5) at its upper end having a central opening (6), an inlet duct (10) for tangential entry of a mixture of gas and catalyst particles from the outlet (12) of a riser reactor (15) of a fluid-bed catalytic cracking plant, a particles discharge duct (16) communicating with the open lower end (4) of the vertical housing (2), and a gas outlet duct (18) having a vertical section (20) which extends through the central opening (6) in the cover (5), which cyclone separator (1) further comprises an open-ended pipe (23) arranged in the central opening (6) so as to define an annular gas inlet conduit (25) between the vertical section (20) and the open-ended pipe (23), and swirl imparting means (30) arranged in the annular gas inlet conduit (25).

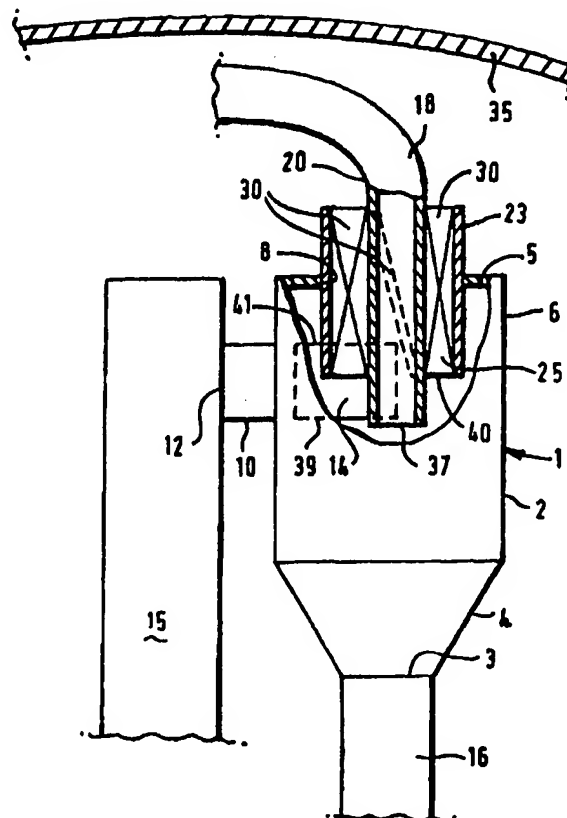
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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/EP97/04881 <b>(22) International Filing Date:</b> 1 September 1997 (01.09.97)  <b>(30) Priority Data:</b> 96202439.4 2 September 1996 (02.09.96) EP <b>(34) Countries for which the regional or international application was filed:</b> GB et al.  <b>(71) Applicant (for all designated States except CA):</b> SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ B.V. [NL/NL]; Carel van Bylandtlaan 30, NL-2596 HR The Hague (NL).  <b>(71) Applicant (for CA only):</b> SHELL CANADA LTD. [CA/CA]; 400 - 4th Avenue S.W., Calgary, Alberta T2P 2H5 (CA).  <b>(72) Inventor:</b> DRIES, Hubertus, Wilhelmus, Albertus; Badhuisweg 3, NL-1031 CM Amsterdam (NL).		<b>(81) Designated States:</b> AU, BR, CA, CN, JP, KR, MX, SG, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>With international search report.</i>

**(54) Title:** CYCLONE SEPARATOR**(57) Abstract**

Cyclone separator (1) comprising a vertical housing (2) open at its lower end (4) provided with a cover (5) at its upper end having a central opening (6), an inlet duct (10) for tangential entry of a mixture of gas and catalyst particles from the outlet (12) of a riser reactor (15) of a fluid-bed catalytic cracking plant, a particles discharge duct (16) communicating with the open lower end (4) of the vertical housing (2), and a gas outlet duct (18) having a vertical section (20) which extends through the central opening (6) in the cover (5), which cyclone separator (1) further comprises an open-ended pipe (23) arranged in the central opening (6) so as to define an annular gas inlet conduit (25) between the vertical section (20) and the open-ended pipe (23), and swirl imparting means (30) arranged in the annular gas inlet conduit (25).



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## CYCLONE SEPARATOR

The present invention relates to a cyclone separator which is applied as a separation stage in a reactor vessel of a reactor riser containing fluid-bed catalytic cracking plant.

5       A fluid-bed catalytic cracking plant includes a reactor vessel, a vertical reactor riser having an upper outlet which is in fluid communication with a separator system arranged in the reactor vessel, and a regenerator vessel. During normal operation, regenerated catalyst  
10 particles and hydrocarbonaceous feed are supplied to the inlet end of the reactor riser in which catalytic cracking of the feed takes place to form a mixture of gaseous product and catalyst particles. The mixture leaves the reactor riser at a high temperature of  
15 between 500 and 540 °C or higher. The mixture of gaseous product and catalyst particles is passed into the separator system where gaseous product is separated from catalyst particles. The gaseous product is removed from the upper end of the reactor vessel, and the catalyst  
20 particles are discharged to the lower part of the reactor vessel where they are stripped. Stripped catalyst particles are passed to the regenerator vessel where coke deposited on the particles during cracking is burnt-off at a high temperature to obtain combustion  
25 products and regenerated catalyst. The combustion products are removed from the upper end of the regenerator vessel and regenerated catalyst is re-used.

Such a fluid-bed catalytic cracking plant is described in European patent application publication  
30 No. 488 549. The known separator system comprises a cyclone separator and an auxiliary cyclone separator to

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provide a two-stage separation. The cyclone separator comprises a vertical housing open at its lower end provided with a cover at its upper end having a central opening, an inlet duct for tangential entry of a mixture of gas and catalyst particles from the outlet of the riser reactor, a particles outlet duct communicating with the open lower end of the vertical housing, and a gas outlet duct having a vertical section which extends through the central opening in the cover and which has an outer diameter which is smaller than the diameter of the central opening. The central opening and the outer surface of the gas outlet duct define an annular inlet port.

The cyclone separator is arranged in the upper part of the reactor vessel, so that during normal operation stripping gas present in the reactor vessel can be drawn into the cyclone separator through the annular inlet port by the difference in pressure between the interior of the reactor vessel and the interior of the cyclone separator.

It is an object of the present invention to improve the efficiency of the known cyclone separator in particular at the level in the cyclone separator where the separation efficiency is low.

To this end the cyclone separator according to the present invention comprises a vertical housing open at its lower end provided with a cover at its upper end having a central opening, an inlet duct for tangential entry of a mixture of gas and catalyst particles from the outlet of a riser reactor of a fluid-bed catalytic cracking plant, a particles discharge duct communicating with the open lower end of the vertical housing, and a gas outlet duct having a vertical section which extends through the central opening in the cover, which cyclone separator further comprises an open-ended pipe arranged

in the central opening so as to define an annular gas inlet conduit between the outer surface of at least part of the vertical section of the gas outlet duct and the inner surface of the open-ended pipe, and swirl imparting means arranged in the annular gas inlet conduit.

US-A-5362379 discloses a cyclone separator comprising a vertical housing provided with an inlet duct for tangential entry of a mixture of gas and solids particles from the outlet of a riser reactor of a fluid-bed catalytic cracking plant. The cyclone separator comprises an open-ended pipe arranged in the central opening of the cover so as to define an annular gas inlet conduit between the outer surface of at least part of the vertical section of a gas outlet duct and the inner surface of the open-ended pipe. According to this publication the stripping gas is directed away from the solids-rich gas region within the separator. As a result, the solids present in the stripping gas will not be effectively separated from the gaseous stream in the cyclone as in the cyclone separator according to the invention.

DE-A-4136935 discloses a cyclone separator comprising a vertical housing provided with an inlet duct for tangential entry of a mixture of gas and solids particles. The cyclone is further provided with means to alter the pressure and flow patterns in the vicinity of the opening of the gas outlet tube when the cyclone is in operation. These means are for example a downward directed gas flow in an annular space around the vertical gas outlet tube. This annular space may be provided with swirl imparting means.

The invention will now be described by way of example in more detail with reference to the accompanying drawing showing schematically a partial longitudinal section of the cyclone separator of the present invention.

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The cyclone separator 1 of the present invention comprises a vertical housing 2 which has a discharge opening 3 at its lower end 4 and which is provided with a cover 5 at its upper end 6. The cover 5 has a central opening 8.

The cyclone separator 1 further comprises an inlet duct 10 extending between the upper outlet opening 12 of a riser reactor 15 and the inlet opening 14 of the cyclone separator 1 for tangential entry of a mixture of gas and catalyst particles into the cyclone separator 1. It also comprises a particles discharge duct 16 communicating with the discharge opening 3 in lower end 4 of the vertical housing 2, and a gas outlet duct 18.

The gas outlet duct 18 has a vertical straight section 20 which extends through the central opening 8 in the cover 5.

The cyclone separator further comprises an open-ended pipe 23 fixed in the central opening 8, wherein an annular gas inlet conduit 25 is defined between the outer surface of the lower part of the vertical section 20 of the gas outlet duct 18 and the inner surface of the open-ended pipe 23. In the annular gas

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inlet conduit 25 swirl imparting means in the form of swirl vanes 30 are arranged.

The cyclone separator 1 of the present invention is arranged in the upper part 23 of a reactor vessel. Since such a reactor vessel is well known, it will not be discussed in detail and only its roof 35 is shown. As a fluid-bed catalytic cracking plant is well known, other parts of such a plant are not shown.

During normal operation a mixture of gaseous product and catalyst particles leaves the reactor riser 15 through opening 12. The mixture is drawn into the inlet duct 10 which opens into the housing 2 so that the mixture enters tangentially into the upper end 6 of the housing 2 of the cyclone separator 1. As a result there is a swirling mixture within the housing 2, and gaseous product is removed from the housing 2 through gas outlet duct 18. Catalyst particles fall to the lower end 4 of the housing 2, and they are discharged via the particles discharge duct 16. The discharged catalyst particles are collected in the lower part (not shown) of the reactor vessel where product adhered to the particles is stripped off by means of stripping gas supplied to the lower part of the reactor vessel. As a result a gaseous mixture of stripping vapour and stripped product passes upwards towards the dilute phase zone in the upper part of the reactor vessel under the roof 35.

This gaseous mixture also contains small amounts of entrained catalyst particles, and these catalyst particles have to be removed from the gaseous mixture. To this end gaseous mixture is drawn into the upper end 6 of housing 2 through the annular gas inlet conduit 25. The swirl imparting means in the form of swirl vanes 30 will impart a swirling motion on the gaseous mixture, and in this way initial separation of entrained catalyst

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particles is effected, which separation continues as the mixture descends in housing 2.

Suitably the swirl imparting means 30 are so arranged that the direction of rotation which they impart is the same as the direction of rotation of the mixture of gaseous product and catalyst particles from the reactor riser 15, so that the latter swirl is amplified which further improves the overall efficiency of the cyclone separator 1.

The ratio of the outer diameter of the vertical section 20 to the diameter of the central opening 8 is suitably in the range of from 0.3 to 0.7.

The lower end 37 of the gas outlet duct 18 is located below the lower edge 39 of the inlet opening 14. However, the open-ended conduit 23 does not extend that far into the cyclone separator 1; it only extends to part of the height of the inlet opening 14. The distance between the lower end 40 of the open-ended conduit 23 and the upper edge 41 of the inlet opening 14 is between 10% and 60% of the height of the inlet opening 14. This is done to maximize the effect which the rotation imparted by the swirl imparting means 30 has on the fluid leaving opening 14.

To accommodate differences in thermal expansion between the housing 2 and the gas outlet duct 18, the swirl imparting means 30 are either fixed to the inner surface of the open-ended pipe 23 or to the outer surface of the vertical section 20 of the gas outlet duct 18, but not fixed to both surfaces.

The number of swirl vanes 30 is suitably between 2 and 8, very suitably between 3 and 6.

The gas outlet duct 18 can be connected directly to a plenum chamber (not shown) which is provided with a gas outlet (not shown) extending through the roof 35, in which case the separator system includes one separation



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stage only. In an alternative embodiment the gas outlet duct 18 can be connected to an auxiliary cyclone separator (not shown), of which the gas outlet which opens into the plenum chamber, in which case the separator system includes two separation stages.

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The upper end of the reactor riser 15 can be arranged in the reactor vessel (as shown in the Figure), or it can be located outside the reactor vessel, so that the inlet duct has to extend through the side wall of

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the reactor vessel.

NEW SET OF CLAIMS

1. Cyclone separator comprising a vertical housing open at its lower end provided with a cover at its upper end having a central opening, an inlet duct for tangential entry of a mixture of gas and catalyst particles from the outlet of a riser reactor of a fluid-bed catalytic cracking plant, a particles discharge duct communicating with the open lower end of the vertical housing, and a gas outlet duct having a vertical section which extends through the central opening in the cover, which cyclone separator further comprises an open-ended pipe arranged in the central opening so as to define an annular gas inlet conduit between the outer surface of at least part of the vertical section of the gas outlet duct and the inner surface of the open-ended pipe, and swirl imparting means arranged in the annular gas inlet conduit.
2. Cyclone separator according to claim 1, wherein the ratio of the outer diameter of the vertical section of the gas outlet duct to the diameter of the central opening in the cover is in the range of from 0.3 to 0.7.
3. Cyclone separator according to any one of claims 1-2, wherein the lower end of the gas outlet duct is located below the lower edge of the inlet duct for tangential entry of a mixture of gas and catalyst particles.
4. Cyclone separator according to any one of claims 1-3, wherein the open-ended pipe extends to part of the height of the inlet duct for tangential entry of a mixture of gas and catalyst particles.
5. Cyclone separator according to claim 4, wherein the distance between the lower end of the open-ended pipe and the upper edge of the inlet duct for tangential entry of a mixture of gas and catalyst particles is between 10% and 60% of the height of said inlet duct.

6. Cyclone separator according to any one of claims 1-5, wherein the swirl imparting means are either fixed to the inner surface of the open-ended pipe or to the outer surface of the vertical section of the gas outlet duct, but not fixed to both surfaces.

7. Cyclone separator according to any one of claim 1-6, wherein the swirl imparting means are between 2 and 8 swirl vanes.

8. Process to separate catalyst particles from a gaseous product leaving a fluid catalyst cracking riser reactor in a cyclone separator according to any one of claims 1-7, wherein the cyclone separator is arranged in the upper part of a reactor vessel and the gaseous product is fed to the cyclone via the inlet duct for tangential entry of the gaseous product resulting in that a gaseous product is removed from the cyclone through the gas outlet duct and catalyst particles are removed from the cyclone through the particles discharge duct after which discharged catalyst particles are collected in the lower part of the reactor vessel where product adhered to the particles is stripped off by means of stripping gas supplied to the lower part of the reactor vessel, resulting in a gaseous mixture of stripping vapour, stripped product and catalyst particles passing upwards towards the dilute phase zone in the upper part of the reactor vessel, wherein the gaseous mixture is drawn into the cyclone through the annular gas inlet conduit.

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